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MC REPORT 112

SUS SOURCE LEVEL COMMITTEE REPORT

November 1975

LONG RANGE ACOUSTIC PROPAGATION PROJECT

OCEAN SCIENCE PROGRAM
MAURY CENTER FOR OCEAN SCIENCE
Department of the Navy
Washington, D.C.

MC REPORT 112

SUS SOURCE LEVEL COMMITTEE REPORT

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This is the final report of the SUS Source Level Committee, which was established by the Manager, Long Range Acoustic Propagation Project to investigate the source levels of small explosive charges, principally SUS. The need for the study arose because of differences in source levels reported by different organizations. The Committee concluded it was not possible to resolve the differences without further experimental work and recommended the performance of a carefully controlled, four phase experiment. The experiment is described

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PREFACE

The Long Range Acoustic Propagation Project, as a part of the U.S. Navy's Ocean Science Program, conducts environmental acoustic measurement experiments in ocean areas of significant interest for ASW. One important technique employed in these experiments, and in other scientific studies of underwater sound, is the use of controlled acoustic sources of known characteristics to measure environmental properties of the sea, such as propagation loss. Among these sources are SUS charges (Signal, Underwater Sound).

In order to measure acoustic phenomena accurately, one must know the source levels of the SUS as a function of frequency and other parameters quite accurately, and the variation expected among production SUS in normal use. There has been an increasing consensus that these properties are not known sufficiently accurately, and there is some disagreement among scientists as to the best values to use. Hence a committee of scientists working in the field was formed to study the problem and to make appropriate recommendations. This document is the final report of that committee.

J. B. Hersey

J. B. Hersey
Deputy Assistant Oceanographer
for Ocean Science

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EXECUTIVE SUMMARY

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This is the final report of the SUS Source Level Committee to the Manager, Long Range Acoustic Propagation Project (LRAPP). The SUS Source Level Committee was established by the Manager, LRAPP to investigate the source levels of small explosive charges, principally SUS. The need for a committee study arose because of differences in source levels reported by different organizations. The most recent values for 1.8 lb SUS charges detonated at depths of 60 ft and 300 ft have been reported by the Naval Surface Weapons Center/White Oak (NSWC/WO), formerly the Naval Ordnance Laboratory, and the Bell Laboratories (BTL). The NSWC values are greater than the BTL values by varying amounts ranging from 1.9 to 7.6 dB in the frequency bands of interest.

The Committee objective was twofold, as follows:

- To investigate the differences in the source levels reported by NSWC and BTL, and, if a satisfactory resolution could be achieved, to recommend a single set of source level values.
- If the Committee could not resolve the reported differences, to recommend a basic

experimental plan which would yield a single set of source levels of known accuracy.

The Committee was unable to resolve the differences between these two data sets. The Committee did determine, however, that data processing at the two laboratories is comparable, and that the differences in absolute levels arise from the recordings themselves. Spectrum levels from the NSWC recordings yielded significantly higher levels than the BTL recordings, with the differences increasing with decreasing frequency.

Inasmuch as it was not possible to achieve a resolution of the problem, other than to identify the source of the problem, the Committee concluded that a new experiment was needed.

The principal goals of a new experiment are:

1. To determine the effective source levels of SUS commonly used in U.S. Navy acoustic transmission loss experiments.

2. To provide a data base for upgrading models which will permit the computation of source levels for other explosive sources. The NSWC model is the prime candidate.

The experiment is described in Chapter 4 of this report. Chapters 2 and 3 discuss the technical aspects of explosive sound and the investigation by the Committee, respectively.

I. BACKGROUND

I. BACKGROUND

The SUS Source Level Committee was established by the Manager, Long Range Acoustic Propagation Project (LRAPP) to investigate the source levels of small explosive charges, principally SUS.

Small charges are used extensively in U.S. Navy experiments to measure low frequency acoustic propagation loss in the world's ocean areas. The accuracy of the measurements depends upon how well the equivalent acoustic source levels of charges are known. The need for a committee study arose because of differences in source levels reported by different organizations. The most recent values for 1.8 lb SUS charges detonated at depths of 60 ft and 300 ft have been reported by the Naval Surface Weapons Center/White Oak (NSWC/WO), formerly the Naval Ordnance Laboratory, and the Bell Laboratories (BTL). The NSWC values are greater than the BTL values by varying amounts ranging from 1.9 to 7.6 dB in the frequency bands of interest.

Other source level values which appear in the literature, or are derivable therefrom, differ from the NSWC and BTL values but generally fall within a few decibels of their limits. The NSWC and BTL values can therefore be viewed as approximate upper and lower bounds to the reported values.

Initial attempts to derive a single set of source levels were directed at reconciling the NSWC and BTL measurements. Preliminary discussions between technical representatives of NSWC, BTL, and LRAPP failed to identify the cause of the reported differences. The SUS Source Level Committee was therefore established to conduct an in-depth investigation. The initial Committee members were:

Dr. Marvin S. Weinstein, Underwater Systems, Inc. (USI), Chairman

Miss Ermine A. Christian, Naval Surface Weapons Center (NSWC)

Mr. Jack M. Busch, Bell Laboratories (BTL)

Mr. Ronald J. Scudder, Western Electric Co. (WECO)

Mr. Louis C. Maples, Naval Underwater Systems Center (NUSC)

Dr. Robert E. Morrison (LRAPP) provided liaison. Mr. Donald L. Sullivan of Arthur D. Little, Inc. (ADL) joined the Committee at a later time.

At its first meeting on June 13, 1974, the Committee agreed to stress the BTL and NSWC data sets, recognizing, however, that neither may be correct.

The Committee objective was twofold, as follows:

- To investigate the differences in the source levels reported by NSWC and BTL, and, if a satisfactory resolution could be achieved, to recommend a single set of source level values.
- If the Committee could not resolve the reported differences, to recommend a basic experimental plan which would yield a single set of source levels of known accuracy.

The Committee was unable to resolve the differences between these two data sets and has therefore proposed a basic experimental plan to obtain the data necessary to resolve this problem. The experiment is described in Chapter 4. Chapters 2 and 3 discuss the technical aspects of explosive sound and the investigation of the Committee, respectively.

II. EXPLOSIVE SIGNALS

II. EXPLOSIVE SIGNALS

The processes involved in the generation of elastic waves by detonation of an underwater explosive charge are quite well known. At the time of detonation a shock wave is propagated outwards and a small sphere of gaseous explosive products at high pressure is formed. The gaseous sphere expands, reducing the pressure in the tail of the shock wave so that the radiated pressure becomes negative relative to the hydrostatic pressure. Minimum radiated pressure occurs when the bubble diameter is at a maximum. The pressure within the bubble is then lower than hydrostatic pressure, and it begins to contract and is carried by momentum through the equilibrium phase to a very small minimum. A positive pressure pulse, known as the first bubble pulse, is emitted and the bubble starts to expand. This cyclical process continues through many cycles, with a positive pressure pulse emitted at each bubble minimum. These are denoted as the 2nd, 3rd, nth bubble pulses. Each pressure pulse removes energy from the gaseous sphere so that each successive cycle takes a shorter time, and the emitted pressure pulses are reduced in energy and amplitude. Cole provides an excellent discussion of these processes. (See Cole, 1965.) Figure 1 from a report by Gaspin and Shuler shows the radiated pressure-time history. (See Gaspin and Shuler, 1971.) For a 1.8 lb charge the

peak pressure of the shock wave at 100 yards is about 45 psi and has an initial exponential decay constant of about 200 microseconds. The first bubble pulse has a peak pressure of about 10 psi with a double exponential time constant of about 600 microseconds. For a detonation depth of 300 feet the first bubble pulse occurs at a time delay (bubble pulse period) of about 40 milliseconds, increasing to about 125 milliseconds for a detonation depth of 60 feet.

The problem with which we are concerned is the determination of the spectral energy content of impulsive signals illustrated by Figure 1. In simplest terms there are two basic methods which can be employed to do this.

- Develop an analytic or graphical form of the pressure-time history. Apply Fourier or FFT techniques to derive the spectral energy levels. This is the basic method employed by NSWC.
- Detonate charges and record the radiated signal. Apply FFT techniques to derive the energy levels. This is the basic method employed by BTL.

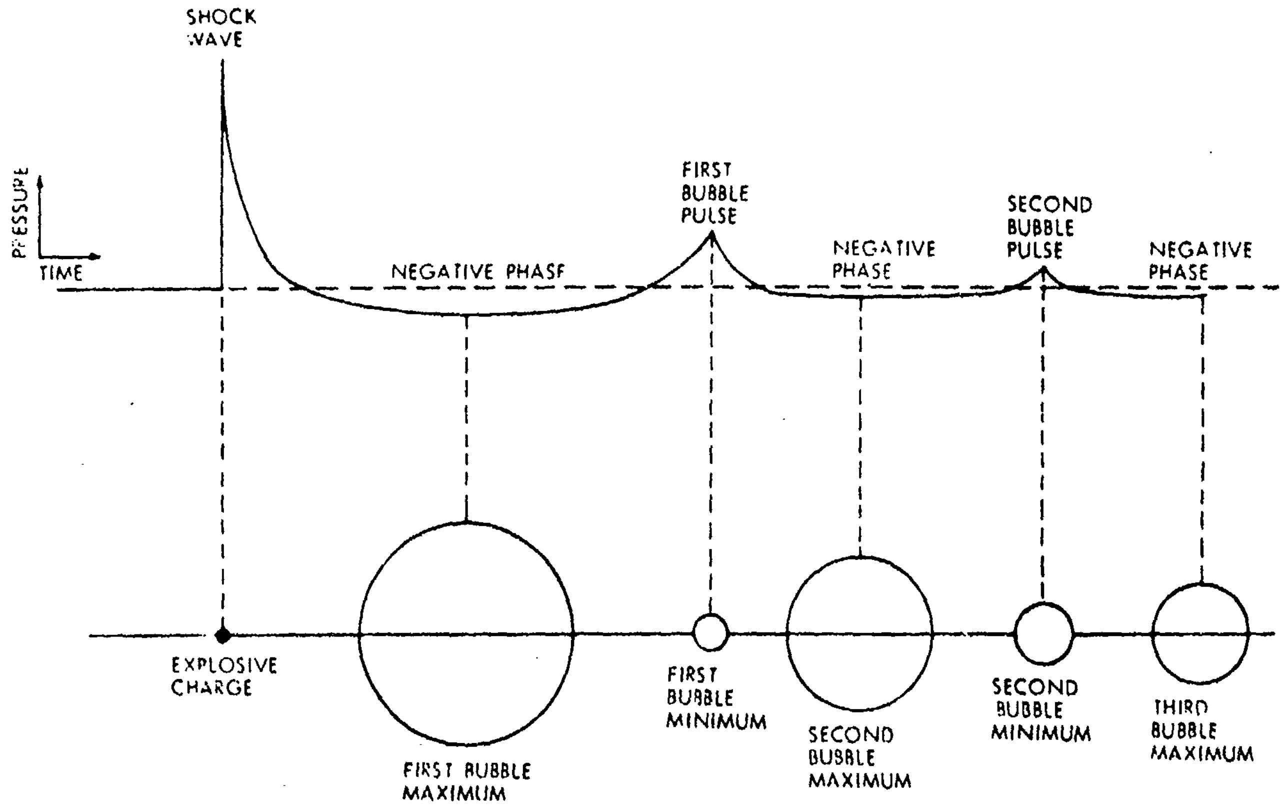

Figure 1. Explosion Bubble and Pressure-Time History

Application of either of these two methods is fraught with difficulty. Experimental measurements are necessary to derive empirically the pressure-time history since theoretical computations do not provide sufficient accuracy. Faithful reproduction of the pressure-time history in an experimental measurement imposes very stringent requirements on the system. The sensor used must be quite small to avoid integration effects, and the overall system response must be flat with zero phase shift over a broad frequency range.

Experimental measurements with shallow charges, whether for direct measurement of spectral energy or for the purpose of defining the pressure-time history curve, are always affected by surface reflections. For a 1.8 lb SUS charge detonated at a depth of 60 feet the bubble pulse period is about 125 milliseconds as noted above. The longest time difference between the direct and surface reflected signal occurs for a sensor directly below the charge and is about 25 milliseconds. Thus, it is not possible to observe the pressure-time history uncluttered by a surface reflection. The received signal consists of the direct signal plus a time delayed, polarity reversed surface reflection whose amplitude is lower by an amount determined by the difference in the two ranges, assuming that the surface is perfectly flat and the shock wave is linearly reflected.

The surface reflected signal will be perturbed by a small, but unknown, amount by several factors; the surface roughness, the degree of non-linearity on reflection at the surface, the propagation of the reflected signal through the tail of the direct signal rather than through undisturbed water, and the known fact that spreading loss as a function of range is different for the various portions of the explosive signal at short range.

Problems with surface reflections decrease as the detonation depth is increased. The bubble pulse period decreases at the same time that the time delay for the surface reflected signal increases. Thus, unadulterated data can be obtained for a 1.8 lb detonation at 800 feet.

Regardless of which of the two procedures is used to determine spectral energy content, surface reflection effects must be removed before the source level can be specified.

With the above general comments in mind we will now consider the various attempts which have been made to develop source level data. Early investigations by Arons, et al, were directed towards describing the pressure-time history of the radiated field and its dependence on charge size, detonation depth, and mea-

surement range. (See Arons, et al, 1948, 1950 and 1954.) Based on these and other results, Weston attempted to describe the pressure-time history in analytic form and derived a closed form Fourier relationship to describe the spectral energy content. (See Weston, 1960.) He used the following relationships to describe the various features of the pressure field:

For the shock wave pressure, p(t), we have:

$$p(t) = P_o e^{-t/t_o}$$

Peak Pressure:

$$P_o = 2.16 \times 10^4 (W^{1/3}/r)^{1.13} \quad \text{lbs/in}^2$$

Positive Impulse:

$$I_o = 1.78\, W^{1/3} (W^{1/3}/r)^{0.94} \quad \text{lb sec/in}^2$$

Time Constant:

$$t_o = 58\, W^{1/3} (W^{1/3}/r)^{-0.22} \quad \mu\text{sec}$$

where W is the charge weight in pounds and r is the range in feet.

Spectral Energy:

$$E_o(f) = \frac{2P_o^2}{\rho c(1/t_o^2 + 4\pi^2 f^2)}$$

where P_o is converted to dynes/cm^2, ρ is the density of the medium in g/cm^3, c is the velocity of sound in the medium in cm/sec, and f is the frequency in Hz.

He assumed that the first bubble pulse is symmetrical and approximates an exponential rise and decay:

Peak Pressure:

$$P_1 = 3,450\ (W^{1/3}/r)\ \text{lb/in}^2$$

Positive Impulse:

$$I_1 = 9.58\ (W^{1/3}/r)\ W^{1/3}\ d_o^{-1/6}\ \text{lb sec/in}^2$$

where d_o = detonation depth + 33 feet

Time Constant:

$$t_1 = I_1/2P_1\ \text{sec}$$

Spectral Energy:

$$E_1(f) = \frac{8}{\rho c}\left(\frac{P_1/t_1}{1/t_1^2 + 4\pi^2 f^2}\right)^2$$

To combine these two prominent features in the pressure-time history, the shock wave pressure field and the first bubble pulse pressure field, it is necessary to know the first bubble pulse period, which is given by:

$$T_1 = 4.36\ W^{1/3}\ (d_o)^{-5/6}\ \text{seconds}$$

Weston treats the negative-going portion of the signal by introducing a constant negative pressure which extends from the shock wave to the nth bubble and whose amplitude is determined by requiring that the total impulse of all components be zero. Applying Fourier integral techniques he obtained the spectral energy levels for the case of two bubble pulse contributions. This

formulation can be readily extended to n bubble pulses. The results obtained by this methodology cannot be expected to be overly precise because of the many simplifying assumptions which have been made. The model deviates from reality in the following major ways:

- The shock wave decay constant is applicable for a period of time no greater than one time constant, after which the deviation is significant.
- The bubble pulse is not symmetrical, so that a single time constant is an oversimplification.
- The negative-going portion of the signal is not accurately represented by a constant negative value.

Additionally, it should be noted that the peak pressure of the shock wave decays as $(1/r)^{1.13}$ while the bubble pulse decays as $1/r$. Thus, the spectral energy levels are a function of the range at which the measurement is made. The range at which the shock wave decay becomes essentially equal to acoustic spreading has been a topic of debate for many years without achieving any community agreement, or a consensus that such a range indeed exists. There are two important consequences which

arise from the above considerations:

- Measurements made at different ranges can be expected to yield slightly different values.
- The desired source levels are those which apply to long range acoustic transmission. This is defined here as the equivalent acoustic source level.

The NSWC model recognizes these difficulties and attempts to deal with them by replacing the analytic forms with pressure-time curves empirically derived from experimental data. (See Gaspin and Shuler, 1971.) Since surface clutter interferes with the measurement of these parameters in the time domain for shallow detonations, certain features of the pressure-time curves are extrapolated from data obtained for deeper detonations. Figure 2 from Gaspin and Shuler compares the spectral energy levels computed in this way with those obtained from the Weston formulation (Weston, 1960). The differences are significant.

Figure 2 also illustrates the importance of carefully defining the measurement bandwidths as well as band locations when specifying source levels. In the vicinity of 30 Hz the spectral source level changes by more than 25 dB from peak to null. To avoid propagation loss errors, the bandwidth

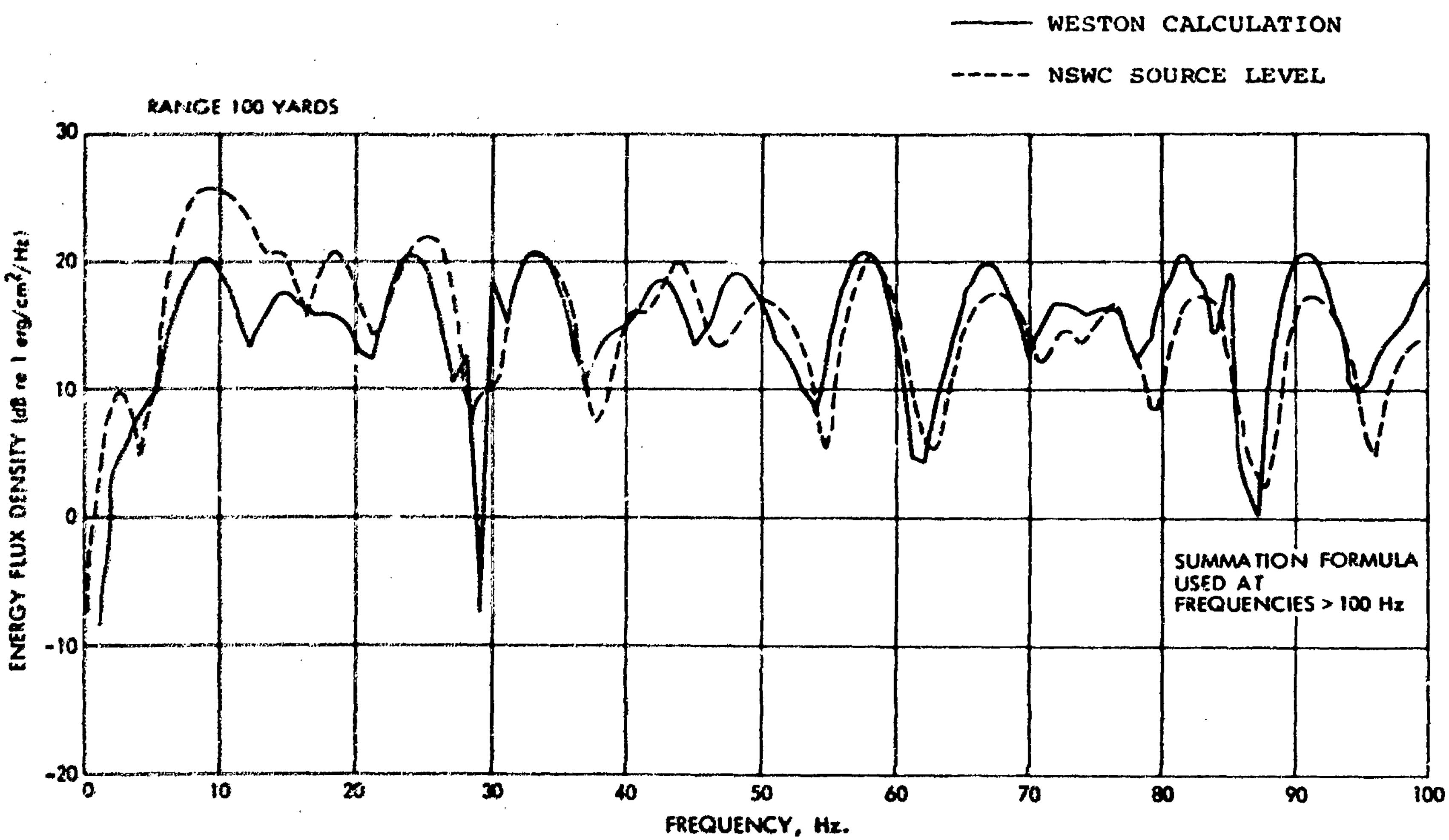

Figure 2. Comparison with Weston's Analytical Formulation
1.8 lb at 60 ft

used to determine the source level must be identical with that used for processing the received signal. The general procedure is to employ bandwidths which are at least equal to the bubble pulse frequency. By straddling a full cycle of the interference pattern the effect of small variations in detonation depth can be minimized. (See Hanna and Parkins, 1974.)

In contrast to analytic or semi-analytic procedures one can employ the alternate methodology of direct measurement. Christian prepared a set of reduced energy flux spectra curves using data from several sources. (See Christian, 1967.)

The most recent set of experimental data are those obtained by Busch, BTL (see Busch, 1973). The measurements were made using moving coil hydrophones from a MILS (Missile Impact Location System) array at 1220 m. The system calibration was computed from the known sensor sensitivity and the cable characteristics. A direct acoustic or electrical calibration of this portion of the system was not possible because the measurement systems have been fixed in place for a number of years. An electrical calibration was inserted at the shore end of the cable. The total system is band limited with frequency dependent phase shift across the pass band. The hydrophones are comparable in size to the spatial extent of the explosive shock wave. As a result, the recorded signal does not display the characteristic pressure-time

history. Linear transform theory predicts that the system should provide correct spectral energy levels.

The measurements were made with Mk 61 and Mk 82 SUS at short ranges of about one nm. The recorded signals were processed by FFT and clearly showed the spectral scalloping associated with the bubble pulse period and the nulls resulting from the combination of the direct and surface-reflected signals. For a specific source depth the frequencies at which the nulls occur depends upon the measurement range and the hydrophone depth. Surface reflection effects were removed by modifying each spectrum by an analytical function of frequency which also had as parameters the travel-time difference and the ratio of the amplitudes for the direct and surface-reflected arrivals. By varying these parameters data were obtained which permitted examination of the entire frequency band of interest.

Table 1 compares the source levels obtained by Weston, Christian, Gaspin and Shuler, and Busch. These are for 1.8 lb charges detonated at 60 and 300 feet and are given in $ergs/cm^2/Hz$ at 1 yard for 1/3 octave bands centered at the designated frequencies. As is apparent, the four data sets are quite different. The differences between the Weston and the Gaspin and Shuler data are known to be due to the replacement of the Weston-derived

TABLE 1

SOURCE LEVEL COMPARISON
1.8 lb Charge
dB re: 1 $erg/cm^2/Hz$ at 1 yard
1/3 octave analysis

Frequency	Weston (W)	Christian (C)	Busch (B)	Gaspin & Shuler (GS)	GS-B
60 foot depth					
25	56.3	-	52.4	60.0	7.6
50	55.1	-	53.0	54.9	1.9
100	54.4	-	48.0	53.7	5.7
160	52.2	-	45.6	50.3	4.7
250	50.2	-	-	48.6	-
300 foot depth					
25	58.1	59	55.8	60.7	4.9
50	55.3	53	51.8	55.7	3.9
100	53.8	50	48.7	53.3	4.6
160	52.1	49	46.7	51.5	4.8
250	50.2	48	-	49.1	-

analytic functions by improved empirical functions. The Christian data fall between the Busch and the Gaspin and Shuler data. The last column of Table 1 shows the difference between the Gaspin and Shuler data and the Busch data. The Committee therefore decided to attempt to resolve the differences between the Busch and the Gaspin and Shuler data, as discussed in the following chapter.

III. DATA COMPARISONS

III. DATA COMPARISONS

The initial examination of the Busch (BTL) data and the Gaspin and Shuler (NSWC) data, and their derivation, was directed towards uncovering any inherent scientific weakness which might underlie the measurements and computations. Areas of concern were found for both data sets.

The principal concern with the BTL data is the absence of a complete experimental calibration of the acoustic system. Reliance has been placed on hydrophone sensitivity data collected many years prior to the later measurements and on computation of the effect of the cable. The shore system was calibrated by inserting electrical signals at the hydrophone cable termination. BTL re-examined their computations and considered the effects of aging on hydrophone performance, concluding that their overall system calibrations were correct. Further, it was noted that the differences between the BTL and NSWC source levels did not indicate a consistent trend as would be expected if the only reason for the difference was due to a calibration error. A secondary concern lies with the size and dynamic range of the sensors employed. Systems analysis indicates that the measured spectral energy levels are correct despite the limited bandwidth and frequency dependent phase shift, provided that the system is linear. Some concern was expressed

that this might not be the case for the sensors employed, since these systems were designed to respond to much lower signal levels than those generated in the source level measurements. Since BTL reappraisal indicated that the dynamic range of the system was adequate, no further progress could be made along these lines.

The principal concern with the NSWC data is the dependence upon extrapolation of parameters from data obtained with detonations at much greater depth, particularly the extrapolation of the shock wave impulse. A re-examination of this matter and an examination of additional signal recordings indicated that the procedures used were reasonable.

It was therefore concluded that there were no obvious explanations for the differences in the two results.

The committee next decided to compare processed results at several facilities using various analog recordings. Data recorded by NSWC and BTL were used as the basis for this comparison. To avoid the effects of surface-reflected signals emphasis was placed on detonations at 800 feet. The BTL data set consisted of signals from five Mk 61 Mod 0 detonated at 800 feet. The NSWC

data set consisted of signals from two Mk 57 Mod 0 detonated at 800 feet.

The BTL and the NSWC shots were spectrum analyzed, corrected for system gain, transmission loss, and bandwidth, and converted to energy spectrum levels at BTL and NSWC. The differences in the results obtained at the two facilities are shown in Table 2 for the NSWC and BTL recordings. The values obtained compared favorably, with the exception of the 223-281 Hz band. The reason for this particular disagreement was not fully explored since the frequencies of interest in this study did not include this band; however, it has been suggested that it may relate to differences in the low pass filters used at the two laboratories. The good agreement at the lower frequencies was confirmed by processing the same recordings at WECO. The causes of small differences were not fully investigated because the consensus of the Committee was that these are not the major contributors to the source level problem; however, NSWC found that increasing the spacing of FFT processing from 0.15 Hz to 1.17 Hz introduced a 0.8 dB change in the 22 to 28 Hz band.

TABLE 2

BTL-NSWC DATA EXCHANGE

$E_{NSWC} - E_{BTL}$ (dB)

BAND LIMITS (HZ)	CENTER FREQUENCY (HZ)	NSWC-800 FEET		BTL-800 FEET	
		SHOT 110	SHOT 222	SHOT 247	SHOT 248
1/3 Octave Bands					
22-28	25	1.3	0.2	-1.9	-1.9
45-56	50	-0.6	0.1	0.0	0.1
89-112	100	0.7	0.5	0.4	0.3
143-180	160	0.1	1.1	0.2	0.1
223-281	250	1.0	1.8	3.7	4.5
Octave Bands					
18-35	25	0.1	0.0	-1.0	-2.1
35-71	50	-0.4	0.0	0.1	0.2

Differences in absolute levels between the two data sets, however, were observed. Table 3 shows the results obtained by NSWC in processing both the NSWC and the BTL recordings. Table 4 shows the results obtained by processing at BTL. Spectrum levels from the NSWC recordings yielded significantly higher levels than the BTL recordings, with the differences increasing with decreasing frequency.

Table 5 shows a comparison of the Gaspin and Shuler model levels with the range of measured levels for the BTL and NSWC recordings. The range of values includes the processing at both BTL and NSWC. As might be expected the NSWC recordings yield levels which straddle the predicted levels, except in the 22-28 Hz band where the measured values are slightly higher. By contrast, the results obtained from the BTL recordings are consistently lower.

Since the Gaspin and Shuler source level values are based principally on experimental data gathered by NSWC, and the BTL source levels are based on data gathered by BTL, these results do not permit a resolution of their differences. However, these differences are positively identified as being principally due to differences in the basic recordings which reflect differences in the systems or calibrations employed. The trends observed in the difference between NSWC and BTL recordings suggest that the frequency response calibrations of either or both the BTL and NSWC systems are suspect.

TABLE 3

NSWC ANALYSIS, BTL-NSWC DATA EXCHANGE
RANGE CORRECTED TO 1 YARD

ENERGY FLUX DENSITY
(dB re: 1 $erg/cm^2/Hz$)

BAND LIMITS (HZ)	CENTER FREQUENCY (HZ)	NSWC-800 FEET SHOT 110 (R=5100')	NSWC-800 FEET SHOT 222 (R=3600')	BTL-800 FEET SHOT 247 (TL=67.5 dB)	BTL-800 FEET SHOT 248 (TL=67 dB)	AVERAGE DIFFERENCE NSWC-BTL
1/3 Octave Bands						
22-28	25	53.8	50.9	47.1	45.9	+5.9
45-56	50	59.3	57.2	54.9	54.0	+3.8
89-112	100	55.3	54.6	51.0	51.4	+3.0
143-180	160	52.7	52.3	50.4	50.4	+2.1
Octave Bands						
18-35	25	54.4	51.6	49.1	47.5	+4.7
35-71	50	58.4	56.9	54.1	53.7	+3.8

TABLE 4

BTL ANALYSIS, BTL-NSWC DATA EXCHANGE
RANGE CORRECTED TO 1 YARD

ENERGY FLUX DENSITY
(dB re: 1 erg/cm^2/Hz)

BAND LIMITS (HZ)	CENTER FREQUENCY (HZ)	NSWC-800 FEET SHOT 110 (R=5100')	NSWC-800 FEET SHOT 222 (R=3600')	BTL-800 FEET SHOT 247 (TL=67.5 dB)	BTL-800 FEET SHOT 248 (TL=67 dB)	AVERAGE DIFFERENCE NSWC-BTL
1/3 Octave Bands						
22-28	25	52.5	50.7	49.0	47.8	+3.2
45-56	50	59.9	57.1	54.9	53.9	+4.1
89-112	100	54.6	54.1	50.6	51.1	+3.5
143-180	160	52.6	51.2	50.2	50.3	+1.6
Octave Bands						
18-35	25	54.3	51.6	50.1	49.6	+3.1
35-71	50	58.8	56.9	54.0	53.5	+4.1

TABLE 5

SOURCE LEVEL COMPARISON
1.8 LBS - 800 FEET
dB re: 1 erg/cm^2/Hz
AT ONE YARD
1/3 OCTAVE ANALYSIS

FREQUENCY BAND	NSWC GASPIN & SHULER MODEL	MEASURED LEVELS (RANGE)	
		NSWC RECORDINGS	BTL RECORDINGS
22-28	49.5	50.7 to 53.8	45.9 to 49.0
45-56	58.6	57.1 to 59.9	53.9 to 54.9
89-112	54.2	54.1 to 55.3	50.6 to 51.4
143-180	51.8	51.2 to 52.7	50.2 to 50.4

Inasmuch as it was not possible to achieve a resolution of the problem, other than to identify the source of the problem, the Committee concluded that a new experiment was needed. This is discussed in the last chapter.

IV. EXPERIMENT

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The principal goals of a new experiment are:

1. To determine the effective source levels of SUS commonly used in LRAPP acoustic transmission loss experiments.
2. To provide a data base for upgrading models which will permit the computation of source levels for other explosive sources. The NSWC model is presently the prime candidate.

SUS source level measurements and analytical predictions have concerned the acoustic community for several decades. The inability of the community to agree on a single set of source levels attests to the difficulty of performing meaningful and accurate measurements. Therefore, it is the opinion of the Committee that a new experiment must be carefully planned, and must address each of the possible sources of past difficulty. The acquisition of a new data set is not sufficient in itself.

The experiment should consist of four phases which could overlap in time and space although they are conceptually separate. The phases are:

1. Equipment preparation and calibration
2. Impulse testing and system comparison

3. Source level measurements on controlled charges

4. Source level measurements on production SUS

It is recommended that a Technical Director be appointed by the Manager, LRAPP for design and execution of the experimental program. The Test Plan should be developed in consultation with the members of the Committee and the participants selected for performance of the experiment. The Test Plan should include the following:

1. Detailed descriptions of measurement systems.
2. Detailed descriptions of test procedures.
3. Detailed descriptions of data analysis methods, including a rationale for comparing sensor systems responses.
4. Schedules for above.
5. Logistics requirements.

The Committee's views concerning critical technical elements of the experiment are described below and are intended to serve as a guide to the Technical Director.

Phase 1. Equipment Preparation and Calibration

It is expected that five or six different types of sensors, together with their preamplifiers, cables and supporting apparatus, will be employed in Phase 2 of the

experiment. These sensors should include moving coil hydrophones of the type employed at MILS stations, large ceramic hydrophones, and Tourmaline, quartz crystal, and small ceramic gages of the type employed by NSWC. Special equipment may have to be designed and built. This phase is intended to include equipment assembly or construction and all conventional static or CW calibration such as might be done at the Underwater Sound Reference Division, Naval Research Laboratory, Orlando, Fla. (NRL Orlando), or equivalent. It is strongly recommended that, to the extent possible, all sensors have a calibration performed by the same facility, or be cross checked. The CW and transient dynamic range of all electronic equipment and, to the extent possible in this phase, the sensors, should be determined along with equipment frequency response (amplitude and phase). Impulse response functions should be measured for all electronics, including recorders.

Preparation of special charges and calibration of CW or other sources are also included in this phase.

Reporting

All calibration procedures and results are to be delivered to the Technical Director in a form suitable for inclusion in an Interim Report on Calibration. Where basically different calibration procedures, such as static vs. CW, are necessary, the rationale for their comparison

shall be included. This is to be an informal report whose purpose is to assure that all calibration results are collected in one place in a complete and coherent format.

Phase 2. Impulse Testing and System Comparison

The purpose of this phase is to extend the previous calibrations to higher pressure levels and transient waveforms and to discover the reason for disagreements among previous measurements. Phases 3 and 4 will be undertaken only after it has been established that all sensor systems give the same results on impulsive signals or that the reason for any disagreement is understood, so that a proper sensor system for Phases 3 and 4 can be selected.

Since it is not the purpose of this phase to measure absolute explosive source levels, an attractive option exists to perform the transient tests in relatively shallow water under carefully controlled conditions with minimum logistic support. The NUSC facility at Seneca Lake and the NUC facility at Lake Pend Oreille both have large barges moored in at least 500 feet of water, with the capability of handling and accurately positioning almost any source and sensor. Conversations with cognizant personnel at NUSC and NUC have revealed strong prejudices against explosives but no specific restrictions on non-

explosive impulse sources, some of which have already been tested at these facilities.

Alternate sites include various fiords on the coast of British Columbia. Two that have been suggested by personnel at the Defense Research Establishment, Pacific (DREP) are Jervis Inlet and Bute Inlet which are off Georgia Strait about 60 and 120 nm from Vancouver. Both have areas where the water depth is 2000 feet. It is possible that some logistic support can be had from DREP in exchange for results. Jervis Inlet may be restricted during the summer because it is a popular yachting area. Bute Inlet is much less populated. Conflicts with fishing interests and environmentalists may arise in either of these areas. Additional problems in this type of environment are currents and salinity gradients. To avoid the complications of an international operation it might be desirable to search for a suitable test site further North along the coast of Alaska.

The advantage of a site where the water depth is 2,000 feet or greater, is that Phase 3 or a major portion thereof could immediately follow Phase 2, provided that on-site data analysis indicates agreement between the various sensors employed. The goal of these tests should be a thorough exploration of the response of all sensor systems over a range of peak pressures. The minimum peak

pressure should be defined by signal-to-noise limitations and the maximum peak pressure by non-linear effects or the possibility of damage. Sensors should be fixed in a known orientation and relative position in a suspension rig designed to assure that all sensors are exposed to the same sound field, and that no spurious signals are introduced by the rig itself. All sensor system outputs are to be recorded on magnetic tape for future processing. Tape duplication will be performed at a quality-controlled facility established for this purpose under the direction of the Manager, LRAPP.

The test procedures, schedules and logistic support should be designed to permit preliminary data analysis and system comparison in the field and to provide for repetition or extension of measurements as necessary to achieve proper system comparisons. Because of differences in frequency response among the various sensors, it will probably be impossible to make quantitative comparisons directly from time series. Therefore, the on-site data processing must include Fourier Transform capability. The sensor system responses will then be compared in the frequency domain, after the application of corrections derived from the Phase 1 calibrations. Again, it should be emphasized that Phases 3 and 4 will not be undertaken until the differences among the sensor systems have been reconciled.

The rationale for sensor comparison must be carefully worked out. The type of impulsive source that is used will have a strong effect on the relative sensor response at high signal levels, if non-linear system effects are present. Candidate sources include a range of explosive yields from detonator caps to 1.8 lb SUS, and impulsive devices such as Hydroshock and PAR. Pulsed CW sources should be considered as a diagnostic aid if, despite all efforts, the various sensors respond differently to impulsive type signals. In this respect the small ceramic hydrophone, of the size of tourmaline gages, but which otherwise behaves as a conventional hydrophone, may be crucial to understanding any observed differences between the outputs of the tourmaline gage and the large ceramic or moving coil hydrophones. It should be possible to calibrate this type of sensor by conventional acoustic methods at NRL, Orlando, and by the static procedures used to calibrate tourmaline gages at NSWC.

It is recommended that during preparation of the test plan the Technical Director and participants in the experiment fully explore the interrelationship between source and sensor selections with special emphasis on the procedures to be used to resolve any observed differences for

the various sensor outputs. It is not sufficient to identify and understand any differences; it is imperative to identify which sensor systems give the correct results if absolute source levels are to be obtained.

Data Analysis and Reporting

Data analysis equipment and procedures in the field should be capable of discerning sensor system non-linearities and comparing sensor system results in sufficient detail that a preliminary judgement of sensor capabilities can be made before test fixtures are disassembled. This will allow for any additional measurements made necessary by preliminary data analysis.

Subsequent data analysis shall be directed toward preparation by the Technical Director of an Interim Report on Impulse Testing. Like the Calibration Report, this is to be an informal report on test geometry, test procedures, data analysis methods and results. Where more than one organization is preparing results, common formats are to be established.

Phase 3. Source Level Measurements on Controlled Charges

The primary purpose of this phase is to provide a data base for interim source levels and for upgrading source level models for explosive sources through determination of accurate pressure and time parameters for use in the models. The source levels of particular concern to the U.S. Navy are those for the standard SUS charges (Mk 61, Mk 64, and Mk 82) detonated at nominal depths of 60, 300, and 800 feet. The U.S. Navy is also interested in other small charges which have been used in propagation studies, such as U. K. 1-lb "scare" charges, and 1/2-lb demolition blocks. The two models of current interest are the Gaspin and Shuler model of NSWC/WO and an analytical model developed at NUSC. Both of these models consist of pressure-time functions whose parameters are derived empirically from pressure-time histories of many explosions. However, the present data base contains no information from charges as shallow as 60 feet and very little information from charges shallower than 1,000 feet. Also much of the data was taken using research-type uncased charges while the SUS are fairly heavily cased. Recommended charge weights and depths are designed to fill in these gaps.

An additional subject for investigation in this phase relates to the establishment of an appropriate range at which to measure SUS source levels, or alternatively, a proper method for extrapolating measured levels beyond the measurement range, as previously discussed in Chapter

II. To accomplish this, controlled charges need to be fired at different ranges. The water depth must also be sufficient to avoid overlap of direct and bottom reflected signals received at the sensors.

Types of Charges

In this phase the emphasis will be on the use of carefully prepared charges electrically detonated at known depths. These precautions are necessary to remove uncertainties in charge yield and detonation depth which are expected from production SUS. The following types of charges will be used:

1. Production SUS modified only for electrical firing. This removes uncertainty in detonation depth, leaving uncertainty in charge weight and homogeneity.
2. Standard SUS casings in which the TNT load has been replaced by Pentolite. This permits close control of the charge weight and homogeneity. Pentolite is used in this series to permit comparison with the next series of uncased charges in which Pentolite must be used.
3. Bare Pentolite charges to determine the effect of the SUS casing. Pentolite is used because cast TNT is difficult to detonate fully in bare form.

4. Bare, pressed TNT of various weights, including 1.8 lbs for comparison with SUS, and 1 lb for comparison with "scare" charges.
5. Bare Pentolite at various depths. (All of the above will be detonated electrically at the standard SUS depths of 60,300 and 800 feet. This series is designed to provide data for other depths which are not standard at present.)

Test Geometry

This phase will require deeper water than Phase 2 since it is necessary to create a fairly large time window between direct arrivals and surface or bottom reflections in order to measure the bubble pulse energy without interference. A time window adequate for the reception of three bubble pulses has been chosen for the preliminary requirement. For 1.8 lb SUS detonated at 60,300 and 800 feet, the required time windows are 275, 95 and 44 milliseconds, respectively. Tables 6 and 7 and Figures 3 and 4 can be used to help decide what water depth is really necessary, since logistic support requirements and experimental difficulties are strongly influenced by water depth specifications.

TABLE 6

TIME WINDOWS BOUNDED BY DIRECT AND SURFACE-REFLECTED ARRIVALS FOR THE THIRD BUBBLE PULSE (MS) FOR 1.8 LB SUS IN 2,000 FEET OF WATER. Left and Right Hand Columns of each Pair are for Surface and Bottom Reflections, Respectively

Bottom Dep*h - 2,000 ft

Source Depth = 60 ft   3 b.p. window = 275 msec

Range (ft)		Receiver Depth 100 ft		500 ft		1,000 ft		1,500 ft	
0	Time (ms)	24	760	24	600	24	400	24	200
1,000		2	593	11	498	17	347	20	177
5,000		<1	261	3	210	5	143	7	72

Source Depth = 300 ft   3 b.p. window = 95 msec

Range (ft)		Receiver Depth 500 ft		1,000 ft		1,700 ft	
0	Time (ms)	120	600	120	400	120	120
1,000		52	467	84	332	103	103
5,000		12	187	23	127	39	39

Source Depth = 800 ft   3 b.p. window = 44 msec

Range (ft)		Receiver Depth 500 ft		1,000 ft		1,200 ft	
0	Time (ms)	200	480	320	400	320	320
1,000		119	367	208	279	232	232
5,000		31	135	62	92	74	74

TABLE 7

TIME WINDOWS BOUNDED BY DIRECT AND SURFACE-REFLECTED ARRIVALS FOR THE THIRD BUBBLE PULSE (MS) FOR 1.8 LB SUS IN 5,000 FEET OF WATER. Left and right hand columns of each pair are for surface and bottom reflections, respectively.

Bottom Depth - 5,000 ft

Source Depth = 60 ft 3 b.p. window = 275 msec

Range (ft)		Receiver Depth 1,000 ft		2,500 ft		4,000 ft	
0	Time (ms)	24	1600	24	1000	24	400
1,000		17	1524	22	974	23	392
5,000		5	1031	11	680	15	280
10,000		2	674	6	434	9	177

Source Depth = 300 ft 3 b.p. window = 95 msec

Range (ft)		Receiver Depth 1,000 ft		2,500 ft		4,700 ft	
0	Time (ms)	120	1600	120	1000	120	120
1,000		84	1507	111	970	117	117
5,000		23	997	54	661	82	82
10,000		12	646	29	417	51	51

Source Depth = 800 ft 3 b.p. window = 44 msec

Range (ft)		Receiver Depth 1,000 ft		2,500 ft		4,200 ft	
0	Time (ms)	320	1600	320	1000	320	320
1,000		208	1448	295	960	311	311
5,000		62	920	142	616	205	[illegible]05
10,000		32	586	77	379	124	[illegible]24

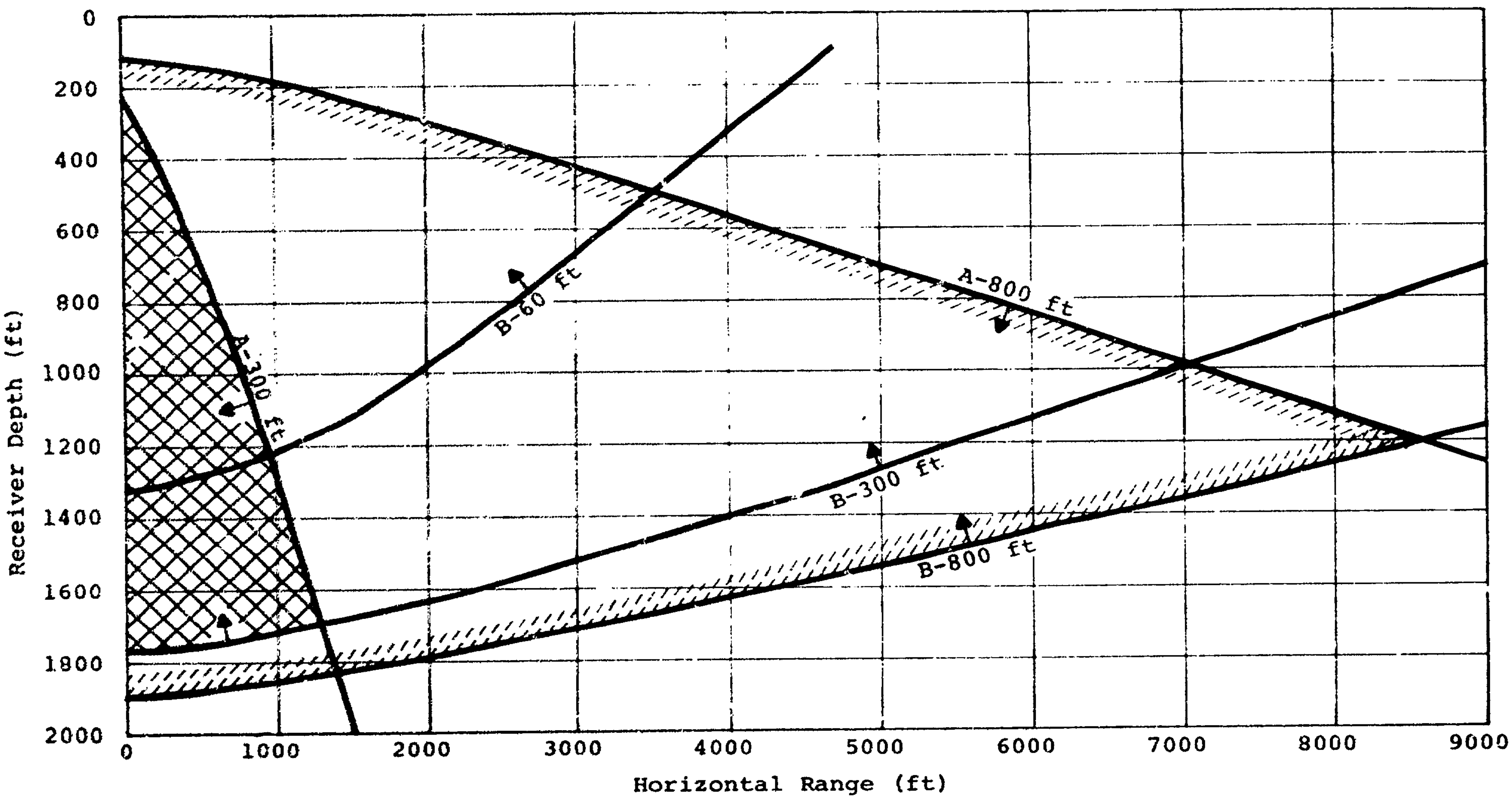

Figure (3). Three Bubble Pulse Criterion Contours for 1.8 SUS in 2,000 ft of water.

A - Limiting Contour for Surface-Reflected Arrivals for Source Depth Shown
B - Limiting Contour for Bottom-Reflected Arrivals for Source Depth Shown

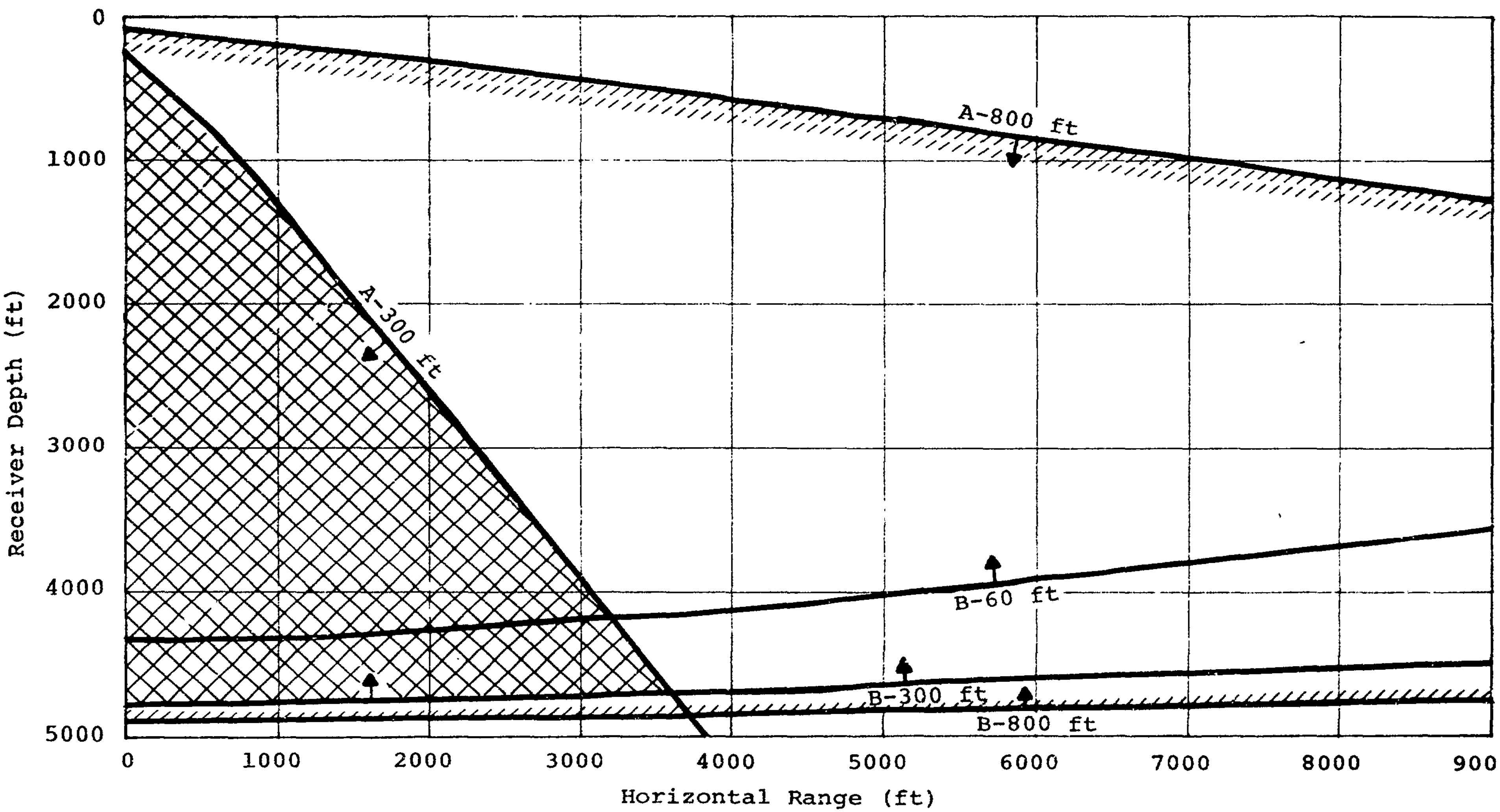

Figure (4). Three Bubble Pulse Criterion Contours for 1.8 lb SUS in 5,000 ft of water.

A - Limiting Contour for Surface-Reflected Arrivals for Source Depth Shown
B - Limiting Contour for Bottom-Reflected Arrivals for Source Depth Shown

The Tables show the travel-time differences between direct arrivals and surface or bottom reflected arrivals for various combinations of source depth, receiver depth, bottom depth and horizontal range, for isovelocity water. These time windows can be compared to those required to satisfy the three-bubble-pulse criterion, or any alternative criterion. What the tables say is that there are ranges and receiver depths where the 3 BP criterion is satisfied for both surface and bottom reflections except for 60 foot sources, where a suitable time window can be found only against the bottom reflection. Thus, to obtain true source levels the surface reflection must be deconvolved from the received signal for all 60 foot 1.8 lb detonations. For the 300 and 800 foot depth detonations deconvolution becomes necessary when the surface reflection arrives too early.

Since the 60 foot detonation requires the widest time window, it presents the worst case for investigating the variation of source level with measurement distance. For a water depth of 2,000 feet, the maximum slant range is somewhat less than 5,000 feet if bottom reflections are to be avoided. The peak pressure of the shock wave at this distance is about 2 psi. This pressure is still quite high and a slant range of 5,000 feet is judged to be insufficient

for this investigation. By contrast, in 5,000 feet of water a range in excess of 20,000 feet can be achieved.

Turning our attention to the 300 foot depth detonations, it is noted that at a range of 1,000 feet and a hydrophone depth of 2,500 in 5,000 feet of water the surface reflection arrives after the 3rd bubble pulse, and deconvolution of the surface-reflected signal is not necessary to obtain the source strength. As can be seen from Figure 5, with 300 foot depth detonations, if there are not refraction effects it will be possible to acquire a valuable subset of data, in which the surface reflections arrive at various times relative to the shock and bubble pulses, simply by placing sensors at different locations along an arc of constant radius struck from the (0, 300 feet) coordinate. If the hydrophone is placed within about 100 feet of the water surface, the reflection will arrive before the initial shock wave has decreased to ambient pressure. At a depth of about 500 feet, the hydrophone will record the reflected pulse about mid-way between the shock and first bubble, and at a depth of about 900 feet the hydrophone will see the reflection arrive at about the same time as the first bubble period (41.5 msec). At all the hydrophone positions on the constant radius arc, the direct arrival will be the same, but the reflected wave will have different amplitudes, as well as different arrivals,

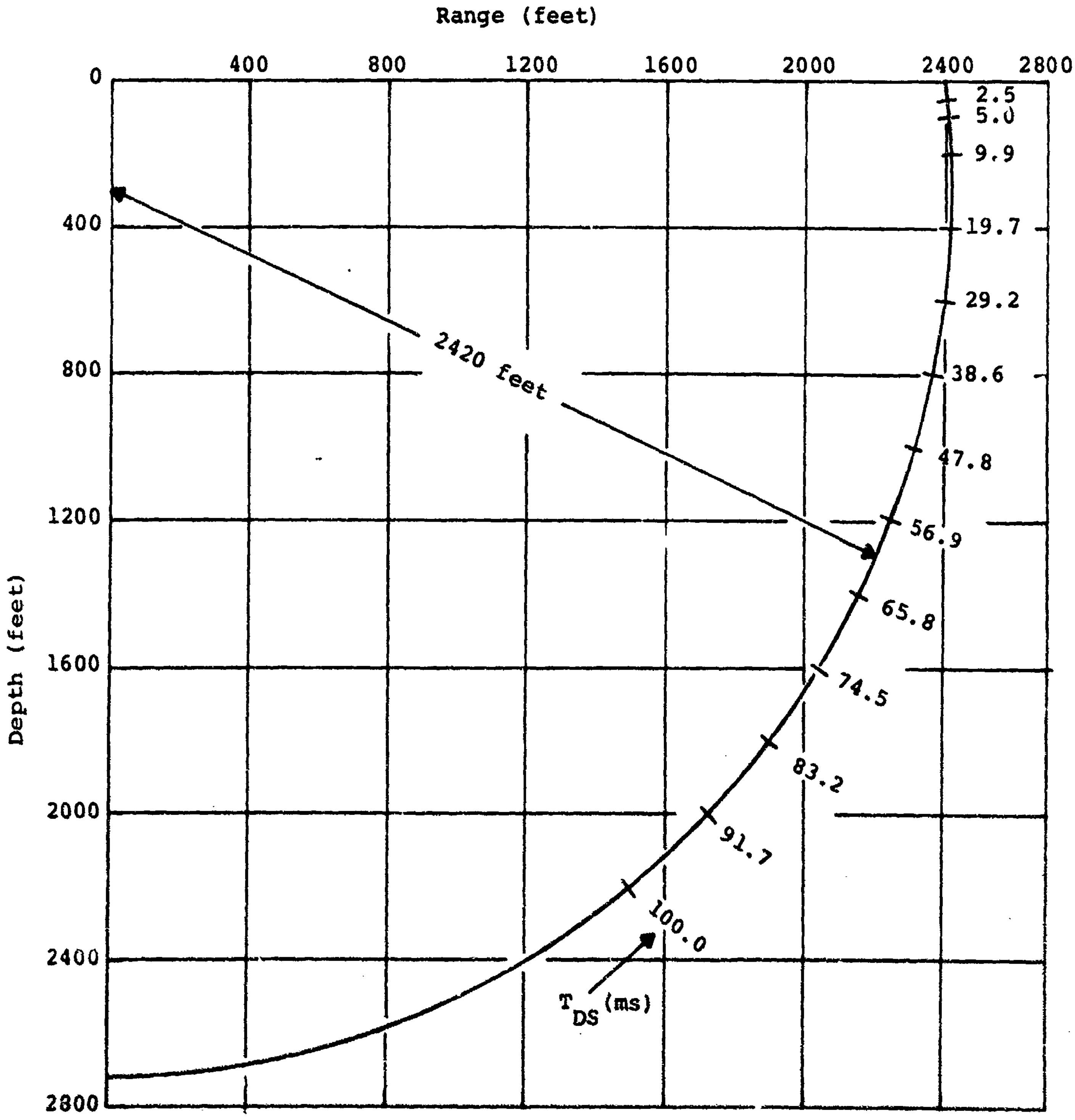

Figure (5). Time Separations of Direct and Surface-Reflected Wave Arrivals, T_{DS}

at the various positions. Thus, by comparing the source levels for these geometries one can investigate the adequacy of the procedures used to remove or deconvolve the surface reflection from the received signal.

Site Selection

It is impossible to specify at this stage where the Phase 3 tests will be performed. There are three major classes of candidates for test sites.

The first class includes such locations as Jervis Inlet and Bute Inlet with water depth of 2,000 feet as discussed in the section on Phase 2 of the experiment. If this site is selected for performance of Phase 2, Phase 3 or a major portion thereof can follow without relocation. However, it is re-emphasized that Phase 3 should not be attempted until satisfactory agreement is achieved between the outputs of the various sensors used. In the event that the outputs are in disagreement, provision should be made for a delay between Phases 2 and 3 to permit study of the data.

The second class of sites is those where the water depth is on the order of 5,000 feet and which offer some sort of shelter, at least from ocean swells. Tongue of the Ocean appears to be the major candidate in this class and offers the possibility of logistic support from the Autec

facility, operated by NUSC. Since the water can be very rough at times, care must be taken to schedule tests during times of the year when the weather is likely to be satisfactory, and event schedules should be sufficiently flexible to permit postponements for limited periods of inoperable weather. There is also a possibility of restrictions by the Bahamian Government on the size of explosive charges.

The third class of sites is the open ocean with deep water. If such a site is selected it should take cognizance of the potential use of MILS hydrophones in Phase 4, so that Phase 4 can follow immediately after Phase 3 without relocation.

Proposed Test Series

Table 8 gives the types and quantities of charges proposed for the Phase 3 measurements. The quantities are rather small because electrical firing is a slow process. Estimated firing rate is about two charges per hour for a total firing time of 49 hours. The small sample size should be partially compensated for by careful preparation of the charges. Test series 1 results can be used to develop a set of interim source levels descriptive of production SUS with only the depth uncertainty removed. For this reason the number of 60 foot

charges has been increased so that measurements can be made for a large number of different geometries. By this means the surface interference nulls can be moved around in the shot spectrum as necessary for mapping the complete spectrum. However, the effects of the direct/surface-reflected interference must still be removed. The numbers of charges shown in Table 8 are the minimum required. Consideration should be given to increasing the sample size at the discretion of the Test Director and participants.

Pulse CW signals should be included in the test series as necessary to permit correlation of results with the Phase 1 and 2 measurements. Environmental data, particularly sound velocity profiles, should be taken as necessary.

Data Analysis and Reporting

See Phase 4.

TABLE 8

PHASE 3 TEST SERIES
ELECTRICALLY FIRED

Test Series	Charge Type	Material	Yield	Depth (ft)	Number of Charges
1	SUS - Mk 61	TNT	1.8 lb	60	12
	SUS - Mk 82	TNT	1.8 lb	300	8
	SUS - Mk 61	TNT	1.8 lb	800	8
	SUS - Mk 64	Tetryl	1.1 oz	60	4
	SUS - Mk 64	Tetryl	1.1 oz	800	4
2	SUS - Mk 61	Pentolite	1.8 lb	60	3
	SUS - Mk 82	Pentolite	1.8 lb	300	3
	SUS - Mk 61	Pentolite	1.8 lb	800	3
	SUS - Mk 64	Pentolite	1.1 oz	60	3
	SUS - Mk 64	Pentolite	1.1 oz	800	3
3	Bare Charges	Pentolite	1.8 lb	60	3
		Pentolite	1.8 lb	300	3
		Pentolite	1.8 lb	800	3
		Pentolite	1.1 oz	60	3
		Pentolite	1.1 oz	800	3
4	Bare Charges	Pressed TNT	1.8 lb	60	3
		Pressed TNT	1.8 lb	300	3
		Pressed TNT	1.8 lb	800	3
		Pressed TNT	0.5 lb	300	3
		Pressed TNT	1.0 lb	300	6
		Pressed TNT	5.4 lb	300	3
5	Bare Charges	Pentolite	1.8 lb	500	3
		Pentolite	1.1 oz	90 to 500	8
				Total	98

Phase 4. Source Level Measurements on Production SUS

This phase, which could run concurrently with Phase 3 at the same site is primarily designed to extend the Phase 3 measurements to include production SUS, deployed in the conventional manner and in sufficient quantity to assure statistical significance in the results.

At this point it is important to reiterate the opinion of the Committee that the experiment must address each of the possible sources of past difficulty which have prevented the prior establishment of accurate SUS source levels agreed to by the acoustics community. Inasmuch as the BTL data were obtained with MILS hydrophones it may be desirable to include that system as one of the measurement tools. The Technical Director, participants in the experiment, and the Committee acting as an advisory board should address this at the earliest opportunity during the planning or experimental stage. There are two primary factors to be considered.

1. Before proceeding with Phases 3 and 4 using sensors agreed upon by the above body of individuals, it should be tacitly understood that the results obtained in Phases 3 and 4 will supersede all prior sets of source level values. If there is any hesitancy in this regard, perhaps arising from the identification of underlying causes for differences in results obtained with different sensors in Phase 2, the

MILS system should be included in Phase 4 for comparative measurements.

2. If it is found during Phase 2 that the sensor outputs are a function of the sensor design, the impact of this on sensor selection when using SUS for acoustic propagation loss measurements should be considered. In that event strong consideration should be given to the use of the MILS system, and the Technical Director should consult with the Manager, LRAPP, concerning the advisability of performing tests with other sensors of interest.

It is recommended that the MILS comparison test be considered for the moment as an option. However, the Technical Director should prepare a tentative plan for such a test so that funding and logistics requirements can be anticipated.

Proposed Test Series

As in Phase 3, it is presumed that a sensor system or combination of systems has been calibrated for use with transient pressures in the 1-10 psi range. For each of the 300 and 800 foot charge depths a single receiver range and depth can be found to satisfy the 3 BP criterion against surface and bottom reflections. For the 60 foot source depth, two or more receiver positions may be used to permit complete mapping of the shot spectra.

Since the production SUS can be deployed rapidly and only a single source-receiver range is required for each source type, each test can be repeated many times for a very small incremental cost. It is recommended that 30 charges of each of the following types be included in the Phase 4 measurements.

Mk 61 at 60 feet

Mk 82 at 300 feet

Mk 61 at 800 feet

Mk 64 at 60 feet

Mk 64 at 800 feet

Data Analysis and Reporting

Analysis and reporting for Phases 3 and 4 are specified together here on the assumption that both sets of measurements are made at the same place and time. If it turns out that the Phase 4 measurements are made at a MILS site, the analysis and reporting schedules will change but the specifications will remain the same.

The following data are to be collected or generated for archival purposes:

1. Analog magnetic tapes of all shot signals.
2. Digital tapes containing time series of all healthy shot signals digitized at a rate to be agreed upon and corrected to sound pressure.

3. Digital tapes containing energy spectra of all shots. Frequency resolution to be agreed upon but should be on the order of 0.15 Hz. Window to be specified.

The set of narrow-band energy spectra will form the basic data set for development of the LRAPP Standard SUS levels. The narrow-band spectral data are to be combined into 1/3 and 1 octave energy levels for all standard ASA bands within the bandwidth of the recordings. Corrections are to be derived for octave and 1/3 octave processing of production SUS signals from inexact depths. Mean and standard deviations are to be determined for all source levels.

A formal report will be prepared by the Technical Director covering all phases of the experiments and their results.

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Subj: DECLASSIFICATION OF LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP) DOCUMENTS

Ref: (a) SECNAVINST 5510.36

Encl: (1) List of DECLASSIFIED LRAPP Documents

1. In accordance with reference (a), a declassification review has been conducted on a number of classified LRAPP documents.

2. The LRAPP documents listed in enclosure (1) have been downgraded to UNCLASSIFIED and have been approved for public release. These documents should be remarked as follows:

    Classification changed to UNCLASSIFIED by authority of the Chief of Naval Operations (N772) letter N772A/6U875630, 20 January 2006.

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3. Questions may be directed to the undersigned on (703) 696-4619, DSN 426-4619.

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By direction

Subj: DECLASSIFICATION OF LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP) DOCUMENTS

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Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
55	Weinstein, M. S., et al.	SUS QUALITY ASSESSMENT, SQUARE DEAL	Undersea Systems, Inc.	750207	ADA007559; ND	U
BKD2380	Unavailable	WESTLANT 74 PHASE 1 DATA SUMMARY (U)	B-K Dyanmics, Inc.	750301	NS; ND	U
TM-SA23-C44-75	Wilcox, J. D.	MOTION MODEL VALIDATION FROM LRAPP ATLANTIC TEST BED DATA	Naval Underwater Systems Center	750317	ND	U
RAFF7412; 74-482	Scheu, J. E.	SQUARE DEAL SHIPPING DENSITIES (U)	Raff Associates, Inc.	750401	ADC003198; NS; ND	U
PSI TR-004018	Barnes, A. E., et al.	ON THE ESTIMATION OF SHIPPING DENSITIES FROM OBSERVED DATA	Planning Systems Inc.	750401	~~ND~~ AD 096582	U
NUSC TD No.4937	LaPlante, R. F., et al.	THE MOORED ACOUSTIC BUOY SYSTEM (MABS)	Naval Underwater Systems Center	750404	ADB003783; ND	U
USI 460-1-75	Weinstein, M. S., et al.	SUS SIGNAL DATA PROCESSING (U) INVESTIGATIONS CONDUCTED UNDER THE DIAGNOSTIC PLAN FOR CHURCH ANCHOR AND SQUARE DEAL SHOT DATA (U)	Underwater Systems, Inc.	750414	ADC002353; ND	U
Unavailable	Ellis, G. E.	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING	University of Texas, Applied Research Laboratories	750618	ADA011836	U
Unavailable	Edelblute, D. J.	OCEANOGRAPHIC MEASUREMENT SYSTEM TEST AT SANTA CRUZ ACOUSTIC RANGE FACILITY (SCARF)	Lockheed Missiles and Space Co., Inc.	751015	ADB007190	U
Unavailable	Unavailable	SUS SOURCE LEVEL COMMITTEE REPORT	Underwater Systems, Inc.	751105	ADA019469	U
Unavailable	Hampton, L. D.	ACOUSTIC BOTTOM INTERACTION EXPERIMENT DESCRIPTION	University of Texas, Applied Research Laboratories	760102	ADA021330	U
PSI-TR-036030	Turk, L. A., et al.	CHURCH ANCHOR: AREA ASSESSMENT FOR TOWED ARRAYS (U)	Planning Systems Inc.	760301	ND	U
NUC TP 419	Wagstaff, R. A., et al.	HORIZONTAL DIRECTIONALITY OF AMBIENT SEA NOISE IN THE NORTH PACIFIC OCEAN (U)	Naval Undersea Center	760501	ADC007023; NS; ND	U
NRL-MR-3316	Young, A. M., et al.	AN ACOUSTIC MONITORING SYSTEMS FOR THE VIBROSEIS LOW-FREQUENCY UNDERWATER ACOUSTIC SOURCE	Naval Research Laboratory	760601	ADA028239; ND	U
ARL-TR-75-32	Ellis, G. E.	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING	University of Texas, Applied Research Laboratories	760705	ADA028084; ND	U
Unavailable	Unavailable	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING	University of Texas, Computer Science Division	761013	ADA032562	U
TTA83676285	Unavailable	ANALYSIS PLAN FOR NARROWBAND/ NARROWBEAM AMBIENT NOISE (U)	Tetra Tech, Inc.	761112	ADC008275; NS; ND	U
USI 564-1-77	Wallace, W. E., et al.	REPORT OF CW WORKSHOP. NORDA, BAY ST. LOUIS, MISS., 28-29 SEPT 1976	Underwater Systems, Inc.	770124	ND	U